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MR J. S. SAWYER, F.R.S.

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RETIREMENT OF MR J. S. SAWYER, F.R.S.

On the retirement of Mr J. S. Sawyer as Director of Research on 19 June 1976, the Meteorological Office lost its most distinguished scientist and one who, over more than a decade, has exerted immense influence on his Directorate composed of powerful research teams working on most of the major problems of meteorology. Few have made such a wide and deep study of the whole subject as John Sawyer who has an unrivalled understanding of atmospheric behaviour and a profound feeling for the significant problems and of the difficulties that may delay their solution. This insight and knowledge, together with his objectivity and superb judgement, have enabled him to provide the necessary leadership and firm guidance for our many extremely able and ambitious young scientists and, while giving them a good deal of freedom in execution, he has never allowed them to lose sight of the main targets and priorities.

Mr Sawyer's personal researches, mainly devoted to analytical and theoretical investigations of the structure and dynamics of weather systems ranging in scale from lee waves to the global circulation of the atmosphere, have always been motivated by a keen awareness of practical problems and a strong desire to improve standards of weather forecasting. After serving for nine years as a forecaster in the United Kingdom and in South-east Asia, he played a key role as a research scientist in pioneering numerical weather prediction in the Meteorological Office. His seminal paper with F. H. Bushby, 'A baroclinic model atmosphere suitable for numerical integration', published in the *Journal of Meteorology* in 1953, laid the foundations for the first fully operational, three-level baroclinic model. He was also responsible for initiating the development of the first operational ten-level primitive-equation models operating on both hemispheric and fine-mesh grids which provide the basis of operational forecasting in the Meteorological Office for up to three days (recently six days) ahead.

Among his long list of publications on synoptic meteorology, his early papers on the theory of tropical cyclones and on the structure of the intertropical front over north-west India, published in 1947, his outstanding analysis of the structure and circulation of fronts published in 1956 and 1958, and his Presidential Address to the Royal Meteorological Society in 1964 on 'Meteorological analysis' deserve special mention. Mr Sawyer took advantage of the Meteorological Office's first computer to carry out, with G. A. Corby, a series of important theoretical studies of airflow over mountains, gravity waves and problems arising in the numerical solution of the dynamical equations. These

outstanding achievements were recognized by his election to Fellowship of the Royal Society in 1962 and by his Presidency from 1963 to 1965 of the Royal Meteorological Society, which awarded him the Hugh Robert Mill Medal in 1956, the Buchan Prize in 1962 and the Symons Memorial Gold Medal in 1971. In 1973 the World Meteorological Organization awarded him its highest honour, the IMO Gold Medal and Prize, for his outstanding contributions to dynamical meteorology and to international collaboration in meteorology.

Although John Sawyer never seeks the limelight and does not enjoy travelling, hotels, and international conferences, he has responded generously to the many calls on his time by national and international bodies seeking his advice and help. In particular he has been a member of the Joint Organizing Committee for GARP since its inception, was Vice-President of the WMO Commission for Atmospheric Sciences from 1961 to 1968 and President from 1968 to 1974. At home, he served as Editor of the *Quarterly Journal of the Royal Meteorological Society* from 1959 to 1961, as Chairman of the British National Committee for Geodesy and Geophysics from 1966 to 1972, and he has been Chairman of the Royal Society Committee on GARP since 1974. In all these tasks, his deep understanding of the scientific problems, his sound judgement and impartiality and, above all, his extraordinary personal modesty, have earned him the respect, affection and gratitude of meteorologists everywhere. It has been a privilege and a pleasure to work closely with him during this most exciting decade of meteorological advance.

Mr Sawyer's knowledge and advice will be greatly missed, but his colleagues will be glad to know that he will continue to serve on the Council of the Natural Environmental Research Council, on the Scientific Advisory Group of the European Centre for Medium Range Weather Forecasts, and on Royal Society and Meteorological Office committees.

We wish him and Mrs Sawyer a long and happy retirement in their new home in the West Country.

B. J. MASON

551.507.321.2

SOME ASPECTS OF THE SWINGING OF BALLOON-BORNE PAY-LOADS

By R. E. W. PETTIFER and R. G. FLAVELL

SUMMARY

Detailed analysis of the output record of a simple photo-electric attitude sensor has revealed considerable information about the swing behaviour of small pay-loads carried by single balloons. Earlier findings that slow rates of ascent (less than 2 m/s) are correlated with small swing amplitudes are confirmed and evidence is presented that marked changes in the nature of the package swing are correlated with passage through wind-shear layers.

A twin-balloon rig incorporating a reliable cut-off device for one balloon has been developed and tested and it is concluded that with such a rig large-amplitude swinging is eliminated even for rates of ascent as high as 6 m/s.

Introduction

There are many experiments in atmospheric physics that involve the use of light-weight simple, balloon-borne apparatus and for which a knowledge of the swinging characteristics of the pay-load is either essential or, at least, useful. In most such cases the use of elaborate attitude-sensing devices such as magnetometers or gyroscopes is ruled out by considerations of expense or of weight.

Recently (1974) Foot, Simmons and Whittaker* (hereinafter referred to as FSW) briefly described a simple photo-electric attitude sensor and discussed the results of a flight in which the sensor was used to indicate the extent of the swinging of the pay-load beneath a balloon. The work described in this report was an extension of that done by FSW, and employed an almost identical sensor. It was done as part of a program aimed at developing a suitable ballooning technique for flying an infra-red radiometer for spectroscopic measurements of stratospheric constituents. For this purpose it was necessary to have a fast initial rate of ascent and then, above 15 kilometres, an observation period when, whatever the rate of ascent, the swing of the package was less than 2° on either side of the vertical.

Initial work was done by using single-balloon rigs and the FSW sensor and from this it was found that by careful analysis and the use of a simple calibration technique, considerable information about the pay-load motion could be obtained. The correlation found by FSW between slow rate of ascent and small swings was confirmed but we do not confirm their conclusion of a lack of correlation between pay-load motion and wind shear. An improved balloon rig using two balloons was developed and the results of this technique are discussed below.

The theory of the photo-electric attitude sensor

The basic theory of the sensor has been described by FSW and they show that a solar cell, screened by an opal glass diffuser, will have, for incident sunlight, a response that is approximately proportional to the cosine of the angle of incidence. By using a simple relation between the angular excursion of the package, the solar zenith distance, and the output of the solar cell, FSW avoided the need for sensor calibration. However, the deductions that they made from their recorder traces were very limited and the simple calibration procedure discussed below allows a much more detailed interpretation of the swing information.

The basic geometry for the motion of the package is shown in Figure 1: θ is the zenith distance of the sun; γ is the angle between the plane containing the zenith, the balloon and the sun and the plane containing the zenith, the balloon and the package; α is the instantaneous swing amplitude of the package and δ is the angle between the sun's ray and the normal to the sensor (which is mounted horizontally on the upper face of the package). It can be shown by the application of the spherical cosine rule that

$$\cos\delta = \cos\theta\cos\alpha + \sin\theta\sin\alpha\cos\gamma \qquad (1)$$

and from this equation the sensor output corresponding to any regular oscillatory motion of the package can be predicted.

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* FOOT, J. S., SIMMONS, E. L. and WHITTAKER, A. E.; Measurements of the swing of a balloon payload. *Met Mag, London*, 103, 1974, pp. 110–115.

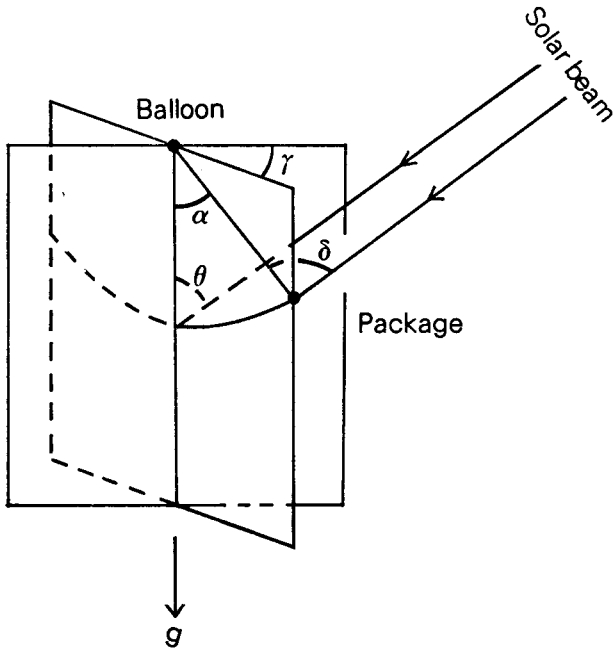

FIGURE 1—THE GEOMETRY OF THE PACKAGE IN FLIGHT

SENSOR CALIBRATION

The sensor output appears as a continuously varying voltage. For radio-transmission purposes this was converted into a modulation frequency and then, after reception, re-converted to a voltage and displayed against time on an XT pen-recorder. Provided that the pen recorder has a linear response it is possible, and convenient, to work in terms of recorder scale-divisions, so that a calibration of α against recorder scale-point is required. During a flight lasting 2½ hours the solar zenith distance changes (by about 16° between 1400 and 1600 GMT in June at latitude 50°N, for example) so that the scale reading arising when the package is vertical ($\alpha = 0$) will also change. Therefore, a calibration curve of scale-reading against the cosine of angle of swing, for swings in the plane containing the balloon and the sun (i.e. $\alpha = 0$) may be obtained by assessing, from the recorder trace, those times at which the package was vertical and determining for them the recorder scale-reading, and, from astronomical tables, the solar elevation.

We considered the package to be vertical at the mid point of small symmetrical excursions of the recorder trace. The restriction to small amplitudes is necessary because of the inherent non-linearity of the cosine function. Two additional calibration points may be obtained before the balloon is launched, although they were not available for FSW's flight. By pointing the sensor directly away from the sun, the scale-point corresponding to $\delta \geqslant 90°$ may be found and by pointing directly at the sun the $\delta = 0$ point may also be found. Owing to the presence of cloud or haze, this last point cannot always be obtained but this does not detract seriously from the usefulness of the method.

Figure 2 is the calibration curve for FSW's data, derived by the method discussed above; the line is a least-squares fit to the points. The large scatter seems to have been due to instability in the electronics of the transmitting/receiving system. Our subsequent flights with more stable electronics have yielded calibration curves with much less scatter than is shown in Figure 2.

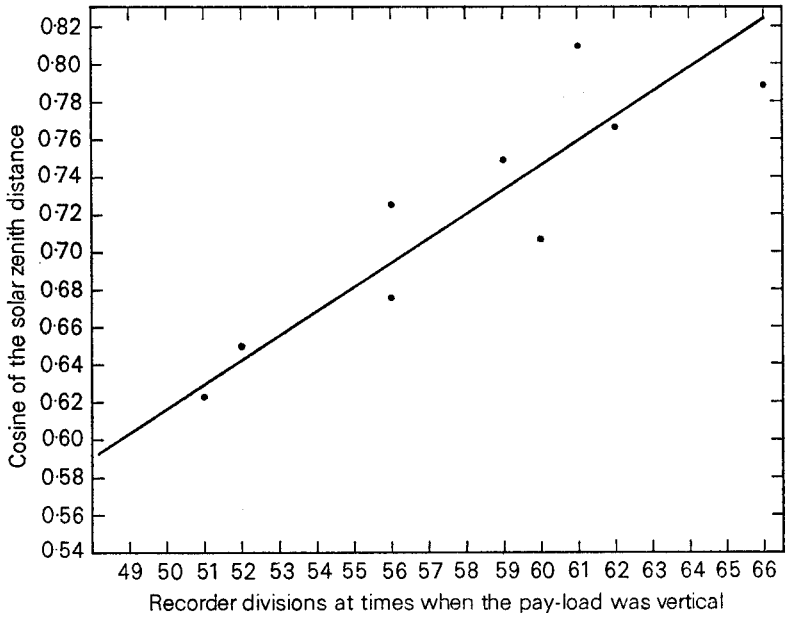

FIGURE 2—THE SENSOR CALIBRATION DERIVED FROM THE FLIGHT TRACE

Data analysis

A particular weakness of the analysis presented by FSW and one not explicitly stated in their text is that the angular amplitudes which they calculate are those appropriate to the component of the total swing that lies in the plane containing the balloon and the sun. They make no attempt to assess the most important parameter, namely the amplitude of the total swing. Even where the sensor output is almost constant, it is not obvious whether this is due to small swings or to swinging (of much larger amplitude) in a plane perpendicular to that containing the balloon and the sun. To illustrate how the technique that we report helps to overcome some of these ambiguities, we analyse below part of the original trace obtained by FSW and discussed by them. Traces that we have obtained by using the sensor and by using single-balloon rigs are very similar.

Figure 3 shows parts of FSW's sensor trace between about minute 60 to minute 63 (their Figure 2); several features of the trace are quite evident. The most obvious among these is a regular oscillation of period about 10 seconds with a definite, but not completely regular, low-frequency modulation; in addition there is the apparent halving of the high-frequency period that occurs at the minimum in the recorder excursions around minute 61·4.

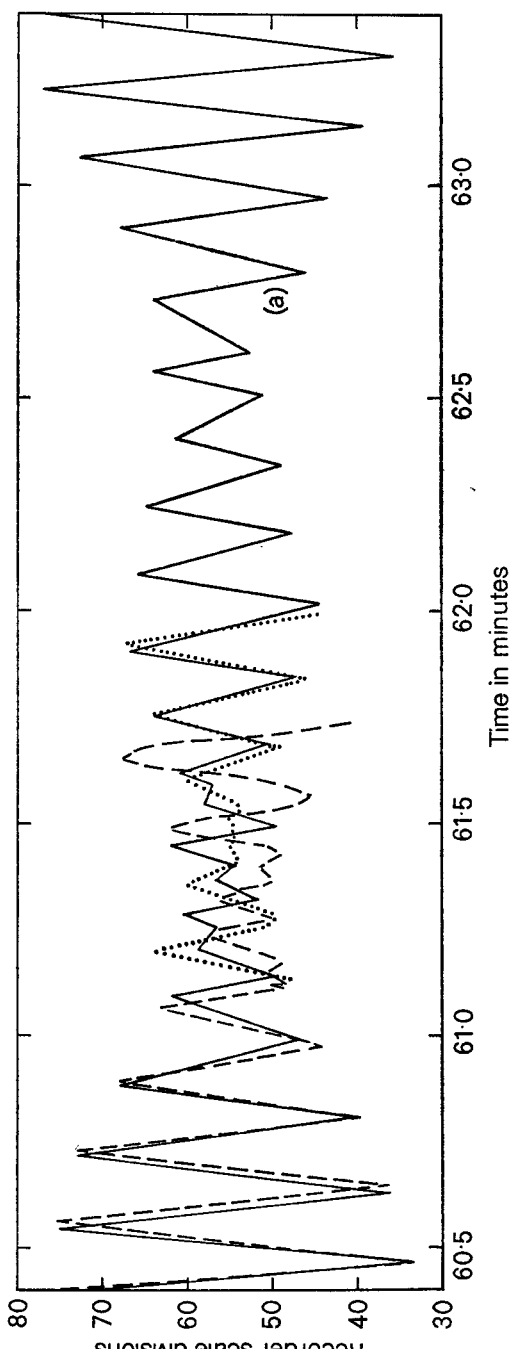

FIGURE 3—PART OF FOOT, SIMMONS AND WHITTAKER'S ORIGINAL FLIGHT TRACE (TIME-SCALE EXPANDED) WITH THEORETICAL TRACES SUPERIMPOSED SHOWING PRECESSING PLANAR SWINGING

·——· Flight trace
·– – –· Theoretical trace: amplitude ± 28°, precession rate 1·45°/s
· · · · · Theoretical trace: amplitude ± 12·5°, precession rate 2·3°/s

To a first approximation, the most reasonable interpretation of this low-frequency modulation might be that the package was executing an oscillation of constant amplitude, the plane of which was precessing steadily relative to the plane containing the balloon and the sun (the principal plane). If this interpretation is correct then the excursion of maximum amplitude is in, or very nearly in, the principal plane and will be approximately a measure of the maximum angular swing of the package and this can be found from the calibration curve (Figure 2). Evidence that this is in fact the correct interpretation of the motion can be seen at the minimum-amplitude portion of the trace. Figure 4 shows the relative output of the sensor for sinusoidal oscillations of the package in a series of planes for a fixed solar zenith distance of 45° and a maximum swing amplitude of ±30°. For the plane perpendicular to the principal plane, marked 90/270, it shows a double maximum, an effect that will result in an apparent doubling of the frequency of the pen-recorder trace. Such a doubling is clearly evident at the minimum-amplitude part of the low-frequency oscillation of Figure 3 and we therefore conclude that at this time the package was swinging across the principal plane.

By assuming that $\gamma = 0$ at minute 60·4 and that $\delta \approx 90°$ at minute 61·4 the rate of precession is easily calculated to be about 1·5°/s for this interval. Superimposed on Figure 3 is the change of amplitude, calculated from equation (1), appropriate to a maximum swing amplitude of 49 recorder divisions and a precession rate of 1·5°/s. From the calibration curve (Figure 2) the swing amplitude of the package, assumed constant, was calculated as ±28°. The agreement between these curves is sufficiently good to allow us to conclude that we have established to a fair degree of accuracy the nature of the package motion over this part of the ascent.

It is clear from Figure 3, however, that the characteristics of the oscillation changed as the angle γ (Figure 1) approached 90°. If we apply the same analysis procedure to the interval from minute 61·25 to minute 62 as we applied to the earlier interval, we obtain a precession rate of about 2·3°/s and a maximum swing amplitude of about ±12½°. The theoretical recorder trace for such values, obtained from equation (1), is also shown in Figure 3 and although this does show a reasonable measure of agreement with the actual recorder trace in the large-amplitude section, no adjustment of the relative phase between the two portions of the calculated curve of Figure 3 can give a reasonable representation of the actual trace through the node of the low-frequency modulation around minute 61·25.

The third section of the actual trace, from minute 62·6 to minute 63·6, shows a very different pattern from the first two, especially in the 'nodal' regions. Notice particularly the 'stretching' of the period of the high-frequency half-cycle marked (a). It is not difficult to show from equation (1) that this feature is characteristic of elliptical swinging by the package, and in Figure 5 the second section of the flight trace is compared with the calculated trace for elliptical swings with a major axis equivalent to a swing angle of 12·5° and a minor axis equivalent to swing angle of ±4·3° together with a precession rate of about 2·3°/s. The fit is remarkably good up to minute 62·7. Thereafter, changes in amplitude (by about a factor of two), phase and precession rate (by about 25 per cent), shown by the second theoretical curve, are required to fit the remainder of the flight trace up to minute 63·4. We therefore deduce that around minute 61·3 the essentially precessing planar swings of the

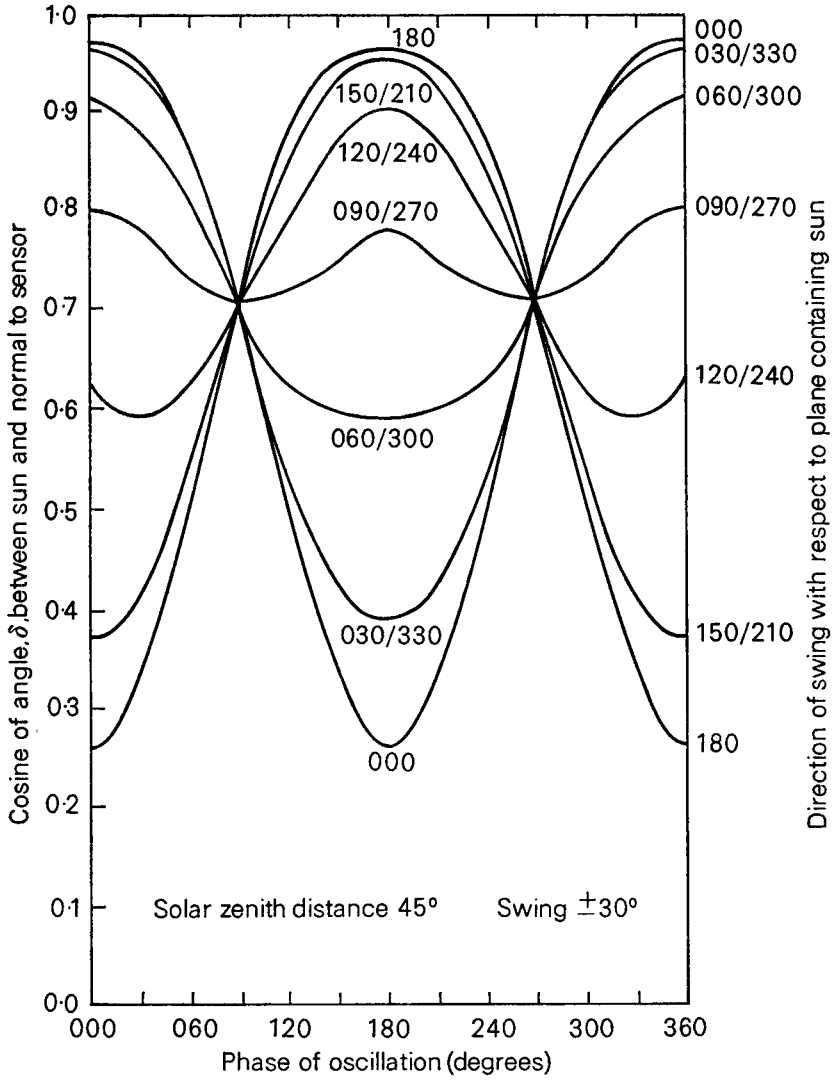

FIGURE 4—RELATIVE OUTPUT OF SENSOR FOR PLANAR SWINGS IN VARIOUS PLANES FOR $\theta=45°$ AND A MAXIMUM SWING AMPLITUDE OF $\pm 30°$

package changed to precessing elliptical swings and that around minute 62·6 these elliptical swings underwent changes of amplitude, phase and precession rate.

Figures 6(a) and 6(b) show respectively the wind speed at balloon height and the track of the balloon during this part of the flight. The direction of swing of the package and the wind direction at balloon height for the critical points during the period corresponding to the traces of Figures 3 and 5 are also shown. Clearly, between minute 61 and minute 62 and again between minute 62·5 and minute 63·0, the balloon passed through a wind-shear layer in which the perturbation of the balloon had a substantial component perpendicular

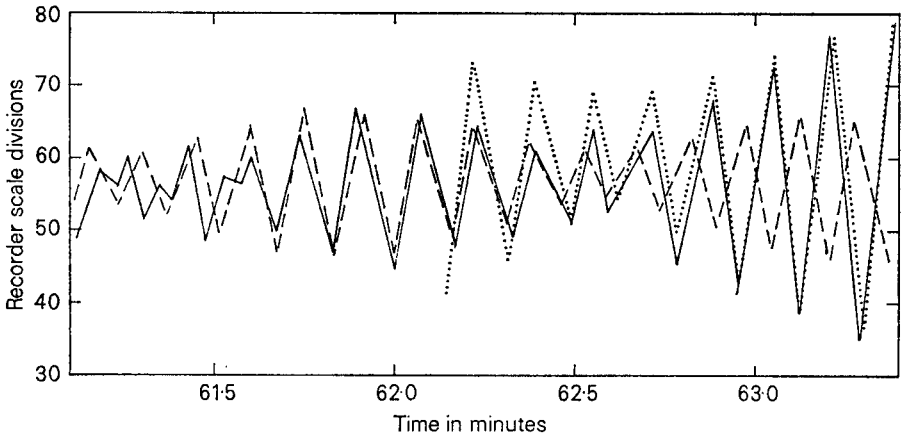

FIGURE 5—PART OF FOOT, SIMMONS AND WHITTAKER'S ORIGINAL FLIGHT TRACE (TIME-SCALE EXPANDED) WITH THEORETICAL TRACES SUPERIMPOSED SHOWING PRECESSING ELLIPTICAL SWINGING

·——· Flight trace
·– – –· Theoretical trace: amplitude ± 12·5° (major axis), ± 4·3° (minor axis), precession rate 2·3°/s
· · · · · Theoretical trace: amplitude ± 26·4° (major axis), ± 9° (minor axis), precession rate 1·7°/s

to the plane of the swing (digitization errors of about ±12·5 m in radar range will have a negligible effect on the calculated wind shears). We conclude, contrary to FSW, that wind-shear layers have a marked effect on the motion of the package; in these cases they induced precessing planar swings to change to precessing elliptical swings and then changed the amplitude and phase of the elliptical swinging. It is easily demonstrated in the laboratory that such changes in the character of the swing of a simple pendulum are consistent with motions of the suspension point across the direction of the swing of the bob.

THE TWO-BALLOON RIG

In order that total flight times should be realistic, due regard being given to radar-range and air-lane problems, it was necessary that the balloon-borne package to be used in our experiments should have a fast initial rate of ascent but that, in order to ensure swinging of very small amplitude during the observational period, the rate of ascent should be slowed to about 1·5 m/s. Various gas-venting techniques were tried in order to reduce the free lift of the balloon and to slow it down, but without the unacceptable penalty in load required by an elaborate, electronically controlled valve none of these proved to be sufficiently reliable. Accordingly it was decided to adopt a twin-balloon rig in which one balloon was the source of almost all the free lift. This balloon was cut free from the rig at a predetermined pressure by the use of a commercially available miniature explosive cut-off device known as a 'Nobel explosive guillotine' and the remaining balloon, having acquired increased positive free lift from the effects of solar heating, carried the package aloft at a much reduced rate of ascent. Several different release arrangements were tried. The two constraints were that the explosive guillotine would not accept a wire thicker than 20 SWG and therefore could not carry the suspension cable

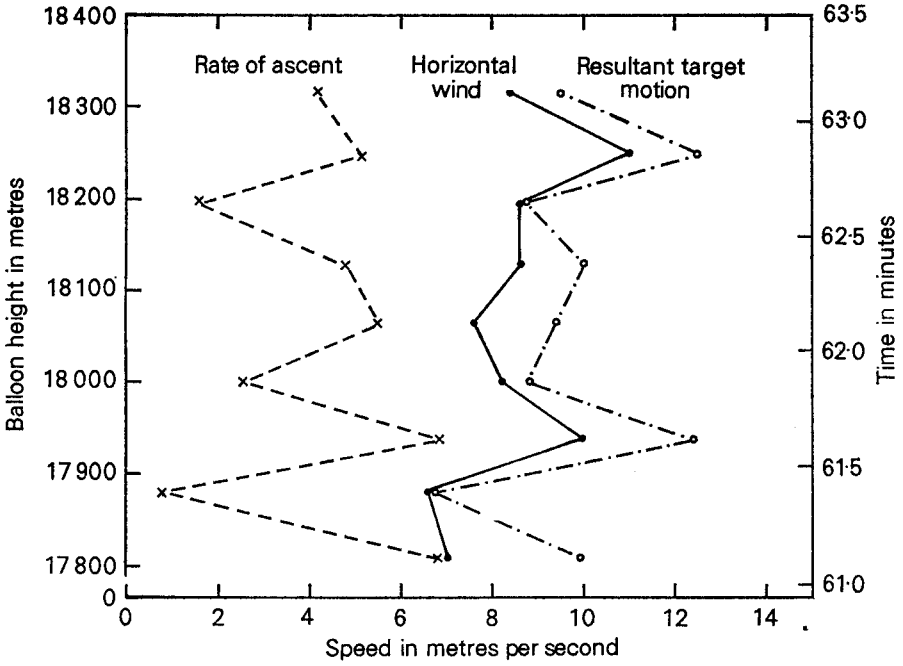

FIGURE 6(a)—RATE OF ASCENT, HORIZONTAL WIND SPEED, AND RESULTANT TARGET SPEED

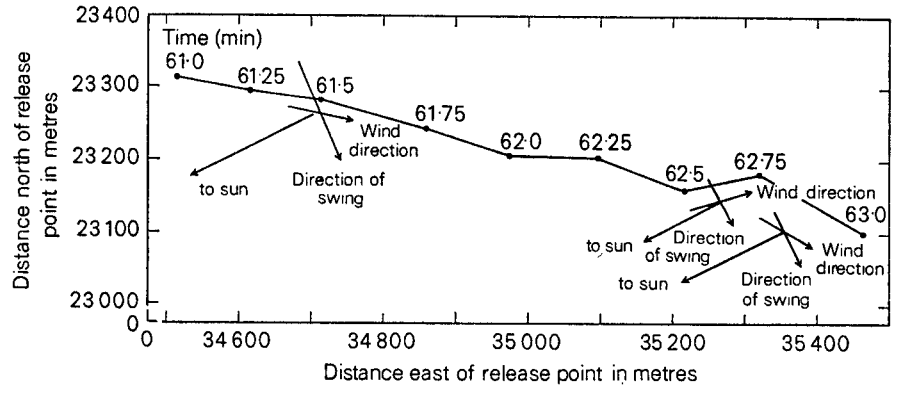

FIGURE 6(b)—THE BALLOON TRACE, PACKAGE SWING DIRECTION, AND WIND AT BALLOON HEIGHT

The OY direction indicates 'north' and the OX direction 'east'.

and the need to ensure that the cable of the released balloon did not foul the remainder of the rig. The solution adopted is shown in Figure 7. The guillotine cut a 26-SWG copper-wire retaining loop, thereby allowing the upper end of the 25-cm long alloy tube to fall away from the balloon cable. The upward motion of the secondary balloon then slid the tube smoothly through the fibre

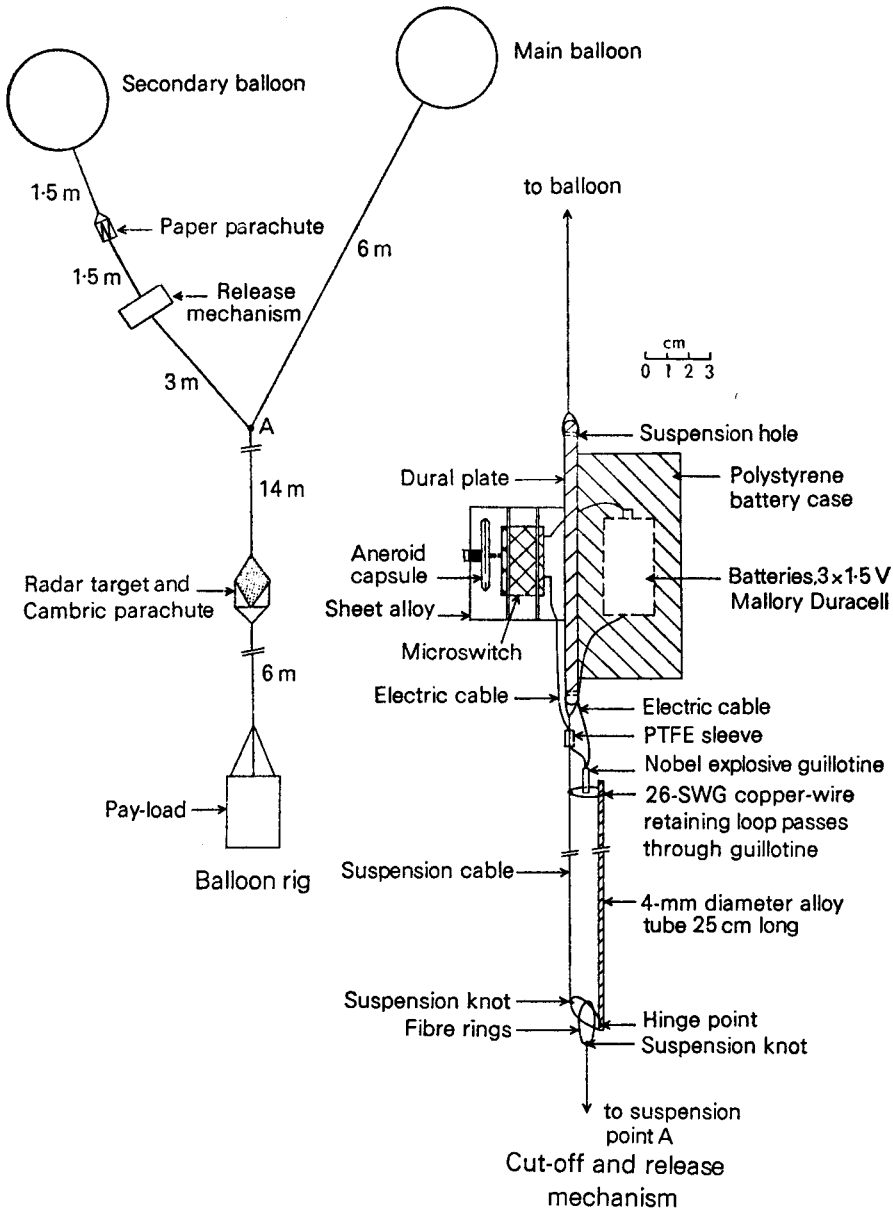

FIGURE 7—THE TWIN-BALLOON RIG AND CUT-OFF DEVICE

ring, parting the two sections of the rig with no danger of entanglement of the two cables. Full details of the rigs used are shown in Figure 7. The load on the main balloon was 5410 g, with a total unladen lift of 5600 g, yielding a free lift of 190 g. For the secondary balloon the equivalent figures were 780 g (comprising the cut-off device and parachute), 5000 g, and a free lift of 4220 g.

This system worked extremely well and reliably released the first balloon at about 100 mb, the pressure-activated cut-off having been preset to fire at this pressure. During the first phase of the ascent the two balloons were observed to rotate slowly round each other, occasionally banging together, but this did not seem to have any deleterious effect on their performance in terms of height reached at burst. As with the single-balloon rigs, once the rate of ascent dropped below 2 m/s the package swings were reduced to around $\pm\frac{1}{2}°$; the significant difference between the twin-balloon rig and the single rig was that for the twin rig visual observation of the package by several observers using a theodolite confirmed the conclusion drawn from the autographic record that, even at rates of ascent as high as 6 m/s, the package swing never exceeded $\pm 15°$ and was frequently less than $\pm 10°$. This is in contrast to single-balloon rigs, for which swings as high as $\pm 50°$ have been observed during fast-rate-of-ascent phases.

Figure 8 shows a typical portion of the output trace produced from the swing-sensor signal for the twin-balloon rig. The irregularities obvious in the single-rig case are not apparent and it does not seem possible to analyse this type of trace in the same way. An analysis of radar data similar to that given in Figure 6 for the single-balloon case showed the effects of wind shears on the motion of the package to be much less marked and there seemed to be a tendency for the resonances that appeared in the dynamics of the single-balloon rig to be damped out in the twin-balloon arrangement. The sharp spikes on the trace were caused by the shadows of the three symmetrical package-suspension strings passing across the face of the sensor as the package spun. From the period of these events the average spin rate can be deduced as approximately 0·5 rev/s.

Conclusions

We have shown that a very simple and cheap attitude-sensing device can yield quite detailed information about the motion of a balloon-borne package for the case of a single-balloon rig in which the motion is reasonably well behaved, although it should be made clear that even in this case there are likely to be some parts of the output record of the sensor that cannot easily be interpreted. We have confirmed the earlier findings of Foot *et alii* that, for single-balloon rigs, rates of ascent below 1·5 m/s are associated with small-amplitude package swings of the order of $\pm\frac{1}{2}°$ but we find that, at faster rates of ascent, marked changes in the nature of the swing behaviour can be correlated with the passage of the balloon through wind-shear layers. We have successfully flown a two-balloon rig incorporating a very efficient and reliable cut-off device to release one balloon and have observed that even at fast rates of ascent up to 6 m/s such a rig does not seem to allow package swing of more than about $\pm 15°$ for the rig dimensions used by us. However, the simple attitude-sensor used successfully on the single-balloon rig did not yield results that could be interpreted in detail when used with the twin-balloon flights.

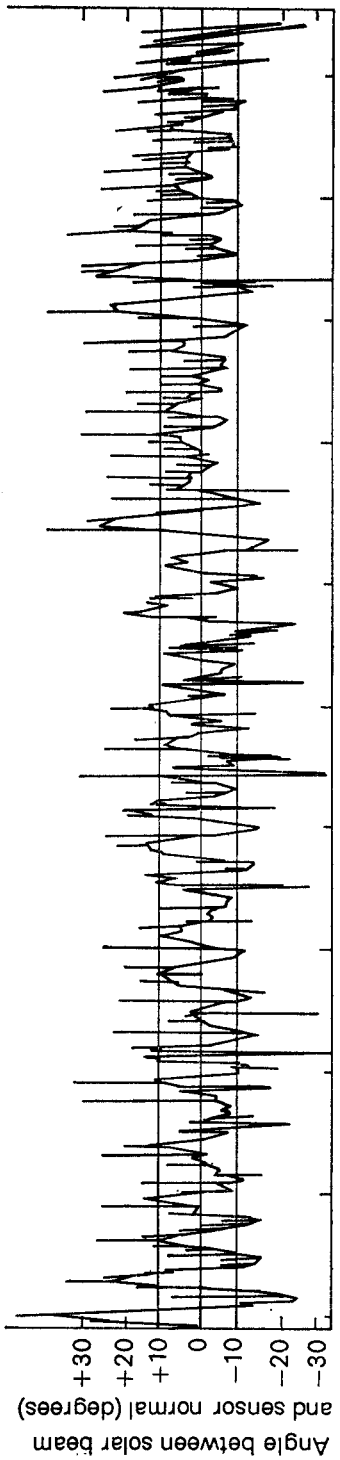

FIGURE 8—FLIGHT TRACE FOR THE TWIN-BALLOON RIG FOR A RATE OF ASCENT OF 6 m/s

ACKNOWLEDGEMENTS

Thanks are due to Dr E. L. Simmons for the loan of his original flight records and for helpful remarks and discussions, to Mr A. J. Thomas, who built the electronics for our sensor flights, to Mr D. E. Chapman who assisted with the calculations and to Mr D. E. Miller for helpful discussions.

551.509.314

A STOCHASTIC MODEL OF THE WEATHER AT HURLEY IN SOUTH-EAST ENGLAND

By P. R. EDELSTEN

(The Grassland Research Institute, Hurley, Berkshire)

SUMMARY

A stochastic model is described which produces a plausible sequence of daily climatic variables for Hurley in south-east England, using random-number generators. A Markov-chain model was used to produce sequences of days of similar weather. Regression analysis was used to obtain equations to predict other variables. The model was tested against the original data and found to work tolerably well, except that the sequencing model required some elaboration.

INTRODUCTION

Climate is the primary driving variable of an agricultural system; climatic variables such as rainfall and radiation determine the biological output from the system through their effect on crop growth and photosynthesis. In grazing systems, the effect on output is largely through herbage production and the quantity of forage available to feed animals. The climate also affects the way in which agricultural systems are managed; for instance, certain operations such as harvesting can only be carried out in favourable weather.

The Systems Synthesis Department of the Grassland Research Institute has, for several years, been involved in constructing simulation models of grazing systems. The author has developed a model of sheep production (Edelsten and Newton, 1975) which goes from herbage production through to the production of lamb carcasses for sale. This model has been used to compare the risks of different management regimes by running the model over a series of years to estimate the year-to-year variability in profitability. The main difficulty was that the herbage growth data used were only available for a 9-year sequence for one site, making the estimates of risk rather tenuous.

In order to be able to run grazing systems models over longer sequences of years and for different sites, it was decided to construct a herbage-growth model for use in the sheep model. The herbage-growth model was to predict herbage growth for a particular site, given inputs of climatic variables. This scheme is illustrated in Figure 1.

FIGURE 1—RELATIONSHIP OF CLIMATE MODEL TO GRAZING MODEL

The simplest way to enter climate data to the herbage model would be to use actual historic data; a magnetic tape of daily climatic data could be kept at the computer and read by models as required. The disadvantage of this approach is that one is limited to the amount of data available; at Hurley, for instance, we have only 16 years' data—not enough to make reliable estimates of the distribution of herbage production.

The alternative approach is to use a stochastic model which produces a plausible sequence of daily climatic variables using Monte Carlo random-number techniques. Such a model can be run over any time-period and can be easily adapted for site-to-site variability. Jones *et alii* (1970) and Dumont and Boyce (1974) have produced climate generators for similar purposes to those outlined above. Jones *et alii* produced daily values for rainfall, temperature and vapour pressure, but did not pay much attention to temperature sequences; Dumont and Boyce's climate generator produced daily values for rainfall, temperature, sunshine, wind speed and vapour pressure, but did not pay as much attention to correlation between the variables as was required in the present study.

Description of the model

The model generates values for the following climatic variables for each 24-hour period:

VARIABLES	UNITS	SYMBOLS
Rainfall	mm	R
Sunshine	h	S
Radiation	mW/cm^2	Z
Minimum temperature	degrees Celsius	T_{min}
Maximum temperature	degrees Celsius	T_{max}
Vapour pressure	mb	V
Wind speed	mile/d	W

(1 mile/d = 0·0186 m/s)

In addition, the following other conventions are used in the descriptions that follow:

R = rainfall today
R_{-1} = rainfall yesterday
R_{-2} = rainfall day before yesterday, etc.
d = day of year
q = quarter number (1st quarter = March–May
2nd quarter = June–August
3rd quarter = September–November
4th quarter = December–February)
k = sequence number (see *Sequencing* below)
s = relative sunshine (see *Sunshine* below)
r = random number between 0 and 1
D = day length in hours.

Sequencing

Hurley weather can be characterized broadly in terms of a series of fairly short sequences of days of similar weather, which could probably be most easily modelled in terms of wind direction and barometric pressure. However, data for these variables were not available and an attempt was therefore made to model the weather sequences in terms of temperature and rainfall, reasoning that weather sequences in summer are often either hot and dry or cold and wet,

while in winter they tend to be either warm and wet or cold and dry. Hot and cold are taken in this context to be relative to the seasonal mean temperature.

The approach taken was to use a second-order Markov-chain model to describe the sequencing of the weather as suggested by Feyerherm and Bark (1965, 1967). There were four possible states for each day:

Cold and Dry (CD)
Hot and Dry (HD)
Cold and Wet (CW)
Hot and Wet (HW).

A 'Cold' day was taken to be one when the mean of the minimum and maximum temperatures was below the seasonal average and a 'Dry' day was one when no rainfall was recorded, the lowest recordable rainfall being 0·1 mm.

Before estimating the transition matrices, the data were smoothed to make the sequences less noisy. Rainfall was smoothed by removing odd wet (or dry) days from sequences of three or more dry (or wet) days so that, for example, the sequence DDWDDWWDW would be smoothed to DDDDDWWWW. Temperature was smoothed by taking a 3-day moving average of the seasonally adjusted mean of minimum and maximum temperature. This made the sequences in the data stand out more clearly and defined the point of transition from one sequence to another more precisely. Weiss (1964) smoothed rainfall by taking a 'Dry' day to be any day when rainfall is below a certain threshold level, but this method seemed unsatisfactory for our purposes because the amount of rainfall is not highly correlated with the rainfall sequence. For example, in summer there is sometimes an isolated day of heavy rainfall in a long sequence of dry days, so that the day is essentially also a 'Dry' day in terms of its sequence type, even though it rained a lot.

The probability of a day being in a particular state was taken to depend on the states of the previous two days, using a second-order Markov chain. Seasonal variation was dealt with by dividing the year into four quarters corresponding to spring, summer, autumn and winter: March–May, June–August, September–November and December–February, and having a separate 16×4 transition matrix for each season, estimated from the data. The sequence k could then be generated by picking a random number r between 0 and 1 (Naylor *et alii*, 1966) and comparing it with the appropriate entries in the transition matrices.

Rainfall

Owing to the smoothing, it was necessary to introduce noise into the generated sequences. This was achieved by counting the numbers of wet and dry days taken out in the smoothing, giving the probability (P) of odd wet (or dry) days in sequences of two or more dry (or wet) days:

$$P \text{ (wet day in a dry sequence)} = 0{\cdot}09$$
$$P \text{ (dry day in a wet sequence)} = 0{\cdot}12.$$

Thus, to determine whether a particular day was actually dry or not, the sequence k was adjusted by comparing another random number r against one of these two probabilities.

Given that it rains, daily rainfall was assumed to come from a gamma distribution with parameters calculated from the original data for each month:

$$p(R) = \frac{\lambda^{\eta}}{\Gamma(\eta)} R^{\eta - 1} \exp(-\lambda R). \quad .. \quad .. \quad .. \quad (1)$$

Values were generated from the distribution using the method of Whittaker (1974).

Sunshine

Hours of sunshine were generated in two steps. Firstly, days when there was no sunshine at all were generated by using an extension to the sequencing model. The probability of zero sunshine was calculated for each season q and sequence k, and also according to whether or not there was zero sunshine the day before. This gave $4 \times 4 \times 2$ probabilities which were calculated from the data.

The second step was to generate the amount of sunshine for days on which this was greater than zero. Day length in hours was calculated from:

$$D = 12{\cdot}2 + 4{\cdot}35 \cos(\{d - 173\} \times 2\pi/365), \quad .. \quad (2)$$

where d = day of year, equation derived from Smithsonian Tables (1951). Relative sunshine $s = S/D$ was found to follow a truncated exponential distribution:

$$f(s) = be^{-bs}/(1 - e^{-b}), \ (0 < s \leqslant 1). \quad .. \quad .. \quad (3)$$

Values of b were calculated from the data for each season, sequence and whether or not there was any sunshine the day before by solving:

$$s = \frac{1}{b} - \frac{1}{e^{b} - 1} \quad .. \quad .. \quad .. \quad (4)$$

iteratively. Equation (4) was derived by applying the maximum-likelihood method to (3). Sunshine hours s could then be generated by using the transformation:

$$\begin{aligned} s &= D \times s \\ &= -D \times \log(1 - \{1 - e^{-b_{qkj}}\} \times r)/b_{qkj}, \quad .. \quad .. \quad (5) \end{aligned}$$

where b_{qkj} = parameter of distribution (3) for season q, sequence k and j set to indicate whether $s_{-1} > 0$,

and r = random number between 0 and 1.

Radiation

Solar radiation was found to be closely related to sunshine:

$$Z = Z_0[0{\cdot}195 + 0{\cdot}569s + (0{\cdot}029 - 0{\cdot}006s)\cos\{(d - 173) \times 2\pi/365\} + e] \quad (6)$$

where Z_0 = maximum radiation
$= 648 + 471 \cos\{(d - 173) \times 2\pi/365\}$
(from MAFF (1967) Table 12, page 74),
s = relative sunshine
and e = error term normally distributed with mean = 0 and standard deviation = 0·079.

Radiation was calculated by using equation (6), the error term being generated by the method of Box and Muller (1958).

Wind speed

Wind speed was found to be highly autocorrelated but showed little correlation with other variables, as in the study of Dumont and Boyce (1974). Wind speed was assumed to come from a gamma distribution (see equation (1)) with

$$\eta = \text{mean}^2/\text{sd}^2$$
$$\lambda = \text{mean}/\text{sd}^2$$

where

$$\text{mean} = b_0 + b_1 W_{-1} \quad .. \quad .. \quad .. \quad (7)$$

and standard deviation

$$\text{sd} = 45{\cdot}3 + 0{\cdot}000797\ \text{mean}^2. \quad .. \quad .. \quad .. \quad (8)$$

Values for b and b_1 in equation (7) were calculated by fitting the equation $W = b_0 + b_1 W_{-1}$ to the original data, for each sequence k and season q, using least-squares regression. Predictions of W using this equation were then grouped into classes and the mean and standard deviation of the predictions in each class calculated. Equation (8) could then be derived by regressing the standard deviations against the means.

Values for wind speed were generated by calculating η and λ from W_{-1} as shown above, and then generating a value from the gamma (η,λ) distribution in the same way as for rainfall (see *Rainfall* above).

Temperature

Minimum and maximum temperatures were autocorrelated and also correlated with other variables.

All the temperature data were seasonally adjusted to start with, using a seasonal trend function:

$$f(T) = T - 9{\cdot}65 - 6{\cdot}41 \cos(\{d - 206\} \times 2\pi/365). \quad .. \quad (9)$$

Equation (9) was derived by fitting a Fourier series to the mean of the minimum and maximum temperatures in the data.

Equations to predict adjusted minimum and maximum temperatures were then found by regression analysis:

$$T_{\text{min}} = a_{\text{kq}} + b_{\text{q}} T_{\text{min}_{-1}} + c_{\text{q}} T_{\text{max}_{-1}} + d_{\text{q}}(s + s_{-1})/2 + e_{\text{q}} W_{-1} + e_{\text{min}} \quad (10)$$

$$T_{\text{max}} = f_{\text{kq}} + g_{\text{q}} T_{\text{max}_{-1}} + h_{\text{q}} Z + i_{\text{q}} s + j_{\text{q}} W + e_{\text{max}}, \quad .. \quad .. \quad (11)$$

where e_{min} and e_{max} are normally distributed error terms. Values for temperature could thus be generated by using equations (9), (10) and (11), the error terms again being generated by the method of Box and Muller (1958).

Vapour pressure

Vapour pressure was closely related to temperature, but also affected by rainfall and radiation:

$$V = V_0(a_{\text{q}} + b_{\text{q}} Z + c_{\text{q}} R + e), \quad .. \quad .. \quad (12)$$

where V_0 = saturated vapour pressure

$$= 6{\cdot}03 + 0{\cdot}499T + 0{\cdot}00692T^2 + 0{\cdot}000571T^3 \quad (13)$$

(by polynomial regression on Table 94, page 352, Smithsonian Tables (1951)),

$T = (T_{max} + T_{min})/2$,

and e = normally distributed error term with mean = 0 and standard deviation = 0·107.

Testing the model

A computer program was written to generate the seven climate variables for each 24-hour period. A listing of the subroutines can be obtained from the author.

To test the program, a run of 100 years was made and the following statistics collected for each of the seven variables:

(i) daily means and standard deviations by month, quarter and year,

(ii) standard deviations of monthly, quarterly and annual means,

(iii) autocorrelations of lag 1, and

(iv) correlation matrices by month, quarter and year.

These statistics were then compared with the 16 years of actual data (9 years for radiation). It was recognized that such a comparison was an invalid test of long-term variability; however, the model was not constructed for use over the long term, the run of 100 years being used only to obtain good estimates of the variability produced by the model.

Means and standard deviations

Table I shows the daily means and standard deviations for the seven climate variables.

The quarters used to tabulate the data are January–March, April–June, July–September and October–December, not the seasonal quarters as used in *Sequencing*. The two sets of data correspond fairly well over the seven variables. This was to be expected since the distributions used ensure that the means and standard deviations converge for large enough samples.

TABLE I—DAILY MEANS AND STANDARD DEVIATIONS

	DATA Quarter				GENERATOR Quarter			
	1	2	3	4	1	2	3	4
Means								
Rainfall (mm d^{-1})	1·58	1·74	2·06	2·16	1·57	1·74	2·19	2·05
Sunshine (h d^{-1})	2·42	5·86	5·42	2·18	2·39	5·56	5·82	2·91
Wind (mile d^{-1})	129·26	121·55	107·81	127·92	129·16	123·01	111·93	122·62
Min. temp. (°C)	1·08	6·70	10·47	3·61	0·65	6·98	10·30	3·28
Max. temp. (°C)	7·83	16·40	20·16	10·70	7·59	16·42	20·18	10·83
Vapour pressure (mb)	7·24	10·55	13·92	9·13	7·04	10·57	13·56	8·90
Radiation (mW cm^{-2})	137·73	426·85	371·93	95·64	132·31	417·95	394·89	113·58
Standard deviations								
Rainfall (mm d^{-1})	3·11	3·91	5·21	4·19	3·03	3·95	5·36	4·19
Sunshine (h d^{-1})	2·85	4·36	3·80	2·56	2·93	4·69	4·64	3·05
Wind (mile d^{-1})	82·48	66·75	64·27	95·21	81·82	73·47	74·10	83·18
Min. temp. (°C)	3·79	3·76	3·10	4·54	3·64	4·00	3·21	4·14
Max. temp. (°C)	3·87	4·40	3·20	4·53	3·39	4·47	3·30	4·14
Vapour pressure (mb)	1·96	2·73	2·52	2·92	1·80	2·97	2·94	2·47
Radiation (mW cm^{-2})	112·28	184·59	164·95	75·36	106·37	199·92	197·75	88·22

Year-to-year variation

Table II shows that the generator produced year-to-year variations in quarterly and annual means for all the variables except wind that were surprisingly close to those in the original data. This was in contrast to the findings of Taylor (1972) who introduced a random variable to produce year-to-year variation in temperature. The reason why this study was more successful is that the sequencing model can produce sequences of values for a variable above or below the seasonal mean, and hence increase the standard deviation of year-to-year variation.

TABLE II—STANDARD DEVIATIONS OF THE MEANS FOR EACH QUARTER AND WHOLE YEAR

	Quarter				Whole year
	1	2	3	4	
Data					
Rainfall (mm d^{-1})	0·39	0·54	0·65	0·65	0·28
Sunshine (h d^{-1})	0·46	0·58	0·89	0·31	0·35
Wind (mile d^{-1})	18·88	17·15	20·54	42·76	18·47
Min. temp. (°C)	1·18	0·53	0·62	0·70	0·45
Max. temp. (°C)	1·28	0·95	1·30	0·65	0·78
Vapour pressure (mb)	0·49	0·58	0·65	0·40	0·36
Radiation (mW cm^{-2})	16·96	29·26	33·79	11·10	16·80
Generator					
Rainfall (mm d^{-1})	0·39	0·52	0·69	0·58	0·30
Sunshine (h d^{-1})	0·33	0·59	0·57	0·38	0·42
Wind (mile d^{-1})	19·31	14·54	16·53	19·34	12·84
Min. temp. (°C)	0·79	0·60	0·69	0·79	0·58
Max. temp. (°C)	0·81	1·00	1·09	0·84	0·91
Vapour pressure (mb)	0·44	0·64	0·77	0·57	0·75
Radiation (mW cm^{-2})	9·93	28·18	26·55	8·61	17·39

Autocorrelation of lag 1

Table III shows that the autocorrelation of rainfall, sunshine and radiation were too low compared with the data. This was because the only lag effects on these variables were those imposed by the sequencing model. To improve this aspect of the model we could either make the sequencing model more elaborate or put autocorrelation specifically into the model for rainfall and sunshine, as we did for temperature and wind.

I believe that it would be more fruitful to use the sequencing approach since this is the only way that the longer-term variations can be modelled.

TABLE III—AUTOCORRELATION COEFFICIENTS OF LAG 1

	DATA Quarter				GENERATOR Quarter			
	1	2	3	4	1	2	3	4
Rainfall	0·34	0·18	0·11	0·16	0·14	0·13	0·10	0·14
Sunshine	0·39	0·30	0·31	0·27	0·25	0·17	0·17	0·27
Wind	0·58	0·61	0·59	0·63	0·60	0·56	0·59	0·64
Min. temp.	0·68	0·59	0·47	0·72	0·61	0·60	0·44	0·70
Max. temp.	0·79	0·75	0·86	0·92	0·70	0·71	0·74	0·92
Vapour pressure	0·58	0·63	0·52	0·72	0·54	0·49	0·33	0·71
Radiation	0·60	0·35	0·53	0·60	0·49	0·21	0·32	0·55

Correlations

Table IV shows the correlation matrices for the real and generated data.

Most of the elements of the correlation matrices corresponded fairly well with those from the actual data, except for the following:

Rainfall and *sunshine*

Again, the sequencing model is to blame since all the correlation between rainfall and sunshine is through the sequencing model.

Sunshine and *minimum temperature*

Minimum temperature is largely dependent on clearness of the night sky. Sunshine hours were included in the temperature model on the assumption that high sunshine hours in the day-time should be correlated with a clear sky at night. This assumption does not seem to be borne out by the results, but there was nothing that could be done about this since night-sky clearness was not included in the data.

TABLE IV—CORRELATION COEFFICIENTS

	DATA Quarter				GENERATOR Quarter			
	1	2	3	4	1	2	3	4
Sun and Rain	−0·18	−0·28	−0·28	−0·23	−0·08	−0·08	−0·10	−0·09
Wind and Rain	0·20	0·07	0·13	0·16	0·13	0·09	0·08	0·11
Wind and Sun	0·04	−0·15	−0·14	−0·11	−0·06	−0·09	−0·09	−0·10
Min. temp. and Rain	0·14	0·11	0·09	0·04	0·12	0·07	0·04	0·09
Min. temp. and Sun	−0·16	−0·10	−0·24	0·01	−0·25	−0·14	−0·30	−0·15
Min. temp. and Wind	0·26	0·01	0·16	0·12	0·33	0·07	0·18	0·20
Max. temp. and Rain	0·11	−0·11	−0·19	0·09	0·05	−0·03	−0·11	0·01
Max. temp. and Sun	0·25	0·49	0·50	0·22	0·20	0·46	0·48	0·25
Max. temp. and Wind	0·24	−0·31	−0·23	0·05	0·24	−0·18	−0·18	0·02
Max. temp. and Min. temp.	0·55	0·52	0·29	0·68	0·46	0·51	0·18	0·59
Vapour pressure and Rain	0·18	0·11	0·07	0·11	0·16	0·08	0·04	0·12
Vapour pressure and Sun	−0·25	−0·08	−0·17	−0·07	−0·22	−0·09	−0·26	−0·08
Vapour pressure and Wind	0·21	−0·12	−0·04	0·05	0·31	−0·04	0·04	0·14
Vapour pressure and Min. temp.	0·73	0·74	0·62	0·79	0·77	0·75	0·64	0·80
Vapour pressure and Max. temp.	0·67	0·68	0·53	0·81	0·63	0·62	0·37	0·75
Radiation and Rain	−0·17	−0·22	−0·29	−0·23	−0·06	−0·06	−0·09	−0·06
Radiation and Sun	0·91	0·86	0·75	0·80	0·84	0·89	0·88	0·84
Radiation and Wind	0·09	−0·29	−0·15	0·03	−0·05	−0·10	−0·08	−0·12
Radiation and Min. temp.	−0·08	−0·19	0·08	0·23	−0·14	0·01	−0·17	0·12
Radiation and Max. temp.	0·43	0·39	0·67	0·47	0·36	0·57	0·55	0·53
Radiation and Vapour pressure	−0·15	−0·23	0·02	0·12	−0·13	0·01	−0·20	0·18

Conclusions

Evaluation of the climate generator depends on the intended application. For example, the model would be unsuitable for estimating the effect of climatic variability on future energy consumption since the limited data that the model was based on may be atypical of long-term trends. In addition, cross-spectral relationships between variables have not been fully explored, and regional climatic variations may make the structure of the model invalid for use over a wider area. However, tests indicated that the model may be suitable for limited applications such as the evaluation of the short-term viability of an agricultural enterprise at a specific location.

Improvements are necessary to the sequencing section of the model but the limited climatic data available for Hurley will make this difficult. Already, some of the elements in the transition matrices have been estimated from less than 10 events, and any attempt to enlarge the transition matrices to include other types of event would make the estimates of probability even more unreliable. One way round this problem might be to use periodic functions as suggested by Feyerherm and Bark (1965).

It should be easy to adapt the climate generator for use in other localities, simply by re-estimating the parameters using data from the area. However, it may be necessary to check the assumptions used in the model if the climate at the locality is very different from that at Hurley.

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REVIEWS

Clouds, rain and rainmaking, by B. J. Mason. 220 mm × 145 mm, pp. viii + 189, *illus.*, Cambridge University Press, Bentley House, 200 Euston Road, London NW1 2DB, 1975. Price £4·95.

The second edition of this well-known book follows its predecessor after an interval of 13 years.

The original selection and ordering of topics are retained in the new edition: cloud forms and features; the nuclei of cloudy condensation; the growth of cloud droplets; the germination and growth of snow crystals; snow, rain and hail; rainmaking experiments; the electrification of thunderclouds. These chapter titles indicate that the author's concern lies almost entirely with the microphysics of the various processes—a suggestion amply confirmed by the detailed text. Thus synoptic aspects of the formation of cloud, precipitation and thunderstorms are only very briefly discussed; while cloud dynamics, though acknowledged by the author to be very important and handled surely by him, are likewise cursorily dispatched.

This is intended to be by way of comment rather than of criticism. A wealth of data is presented relating to the constitution and formation of clouds and to the development within them of precipitation elements and lightning. These data refer both to laboratory experiments made under condition of careful control and to measurements in the 'real' atmosphere where observational methods have included the use of instrumented aircraft and ground radar. The author's main concern is to set the data in their physical and (where applicable) mathematical context, to describe both the relevance and limitations of laboratory experiments to the atmosphere, and to indicate the 'grey' areas of present knowledge and the nature of the barriers to future progress. He achieves this with an economy and fluency of presentation and style which make the book very readable. Its appeal is enhanced by its many fine plates (mostly the same as in the first edition but now distributed throughout the text, at appropriate points, instead of being grouped near the middle), and by an augmented list of simple illustrative experiments.

There are some points at which conciseness may be argued to have been carried too far. Thus the equation 3.1, which is an expression for the time rate of change of mass of an individual cloud droplet due to diffusion of water vapour, is neither obvious from first principles nor does it follow from the text which precedes it. The serious student has reason to pause at such a point and may be forced to refer to the author's more comprehensive text *The physics of clouds*. Specific references to the latter book, or to original sources, are given for various other mathematical derivations.

The newer work reported in this edition is mainly on ice nucleation, hailstone structure and growth, experiments in rainmaking, and the electrification of thunderstorms. These jointly pose the most difficult problems in cloud physics and, not unnaturally, are also those which arouse most controversy. This is not a new situation for thunderstorm electrification—witness, notably, the controversy of the inter-war years between G. C. Simpson and C. T. R. Wilson. The author has been especially active in this field of investigation and devotes much of the book's final chapter to the proposition that the formation and

growth of hail pellets is the primary mechanism of charge separation. Recent correspondence in the meteorological literature suggests that this is a controversy which is unlikely to be settled in the near future.

D. H. MCINTOSH

Environmental data from historical documents by content analysis: freeze-up and break-up of estuaries on Hudson Bay 1714–1871, by D. W. Moodie and A. J. W. Catchpole. 150 mm × 230 mm, pp. xviii + 117, *illus.*, Department of Geography, The University of Manitoba, Winnipeg, Canada R3T 2N2, 1975. Price: $4.

This book describes the procedure used to derive the dates of freezing and thawing of estuaries around Hudson Bay from entries in the records of the Hudson's Bay Company over the period from 1714 to 1871.

It is a very worthwhile enterprise but the description of how it was done makes the dreariest reading imaginable. The oppressive verbiage and mostly unnecessary jargon are exceptionally tiresome to read; in the end the authors admit that what is not precise remains imprecise, and that probabilities have to be handled by arbitrary assumptions.

There is an account of the reliability testing which shows that any errors in the final derivations from the journals arise much more from the imprecision of the content than from the subjective judgment of the interpreters.

In three tables at the end are listed the first date of freezing, the date of final freeze-up and the first date of break-up in the spring for six locations around Hudson Bay from 1715 to the middle of the 19th century. Judging from the tests described in the book, the first dates of freezing and break-up should be reliable enough to assist climatic-change studies of this singular area of the northern hemisphere.

M. K. MILES

A short course in cloud physics (*International Series in Natural Philosophy, Volume 84*), by R. R. Rogers. 205 mm × 125 mm, pp. xii + 227, *illus.*, Pergamon Press Ltd, Headington Hill Hall, Oxford OX3 0BW, 1975. Price: £6·50.

This book is based upon the author's lecture notes for the thermodynamics and cloud physics parts of a graduate course in physical meteorology at McGill University. Therefore naturally, but somewhat unusually for cloud physics texts, the first chapters deal with the thermodynamics of dry and moist air. The concepts of stability and buoyancy are developed from this base and applied to the convective process. The reader is led gently from elementary parcel theory to the modifications necessitated by mixing and aerodynamic resistance.

The development of the theory of droplet growth in non-freezing clouds follows the classical pattern from nucleation, through condensational growth, to coalescence. Then the formation and growth of ice crystals is described in a similar manner before the relevance of these processes to rain and snow formation is assessed.

The subject of cloud dynamics is introduced through a description of the instrument whose use has led to many of the advances in this topic, namely weather radar. This is followed by a short account of the structure and dynamics of precipitation-forming processes ranging from widespread frontal systems to severe convective storms.

The book ends with a brief, qualitative introduction to weather-modification principles, and an account of the fundamentals of cloud modelling. The latter is useful in describing the physical advantages and limitations of some of the possible approaches to the subject. A short bibliography containing references up to 1974 is provided.

The book, as a whole, is disappointing. It does not set out to be, and is clearly not, a major treatise on the subject. The wide range of topics covered, of necessity, leads to a certain superficiality in many areas, and when the author states 'In preparing this material I found it very useful to have at hand the books on cloud physics by Fletcher (1962), Byers (1965) and Mason (1971)', there is a distinct impression that the reader will find it equally useful, and even essential, to do the same. This criticism would be unimportant if the book provided the insights and new perspectives so difficult to achieve in the major works, engrossed as they often are with rigour and the desire for completeness. There is some evidence that Rogers had this in mind, but it is *not* a strong characteristic of the book. The provision of problems at the end of each chapter suggests that he was attempting to develop a quantitative 'feel' for the subject in his readers but even here the lack of accompanying answers to the problems does not encourage the beginner. The book does cover a wide field in a relatively simple quantitative manner but without great authority or novelty of approach.

P. RYDER

Physical and dynamic climatology (*Proceedings of the Symposium on Physical and Dynamic Climatology, Leningrad, August 1971*). 220 mm × 150 mm, pp. 400, *illus.*, World Meteorological Organization, Geneva, 1974. Price: 30 Sw. Fr.

The Leningrad symposium of 1971 was among the first at which the feeling that man's activities might be about to begin to affect global climate was discussed by meteorologists at an international level. Many of those present had strong opinions about the way things were going, and the question of what attitude the science should take in advising governments and peoples about the possible dangers ahead was never far from the minds of the participants.

Reading the proceedings of the symposium which have now been published, one's first thought is that they have been a long time coming, and that work that seemed fresh then is commonplace now after years in which the problems of pollution and climatic change have been discussed, popularized and vulgarized almost *ad nauseam*. Disappointment in the published papers is even

greater when it is realized how much of what was actually presented, and some of it the most relevant to the main topic, is absent, or presented only in the briefest form. This is perhaps inevitable when the issues are delicate, and authors are not necessarily willing to go as far in their written as in their spoken pronouncements; also, of course, many papers have since been published elsewhere and are therefore omitted here. What is left is a very uneven volume with no clear theme running through it. It covers a wide variety of topics ranging from the local climatology of showers to variations of climate on the largest time- and space-scales. Perhaps the main value to western meteorologists will lie in the Soviet contributions which can be read here without the tedium of translation. The papers by Gandin, Shvetz and Yudin, Sergin and Sergin, and Obukhov for example will repay study and indeed seem now of greater interest than the review papers whose relevance is much lessened by the passage of time.

A. GILCHRIST

NOTES AND NEWS

One hundred and twenty-five years ago*

Of late years much attention has been paid to Meteorological phenomena, with the hope of determining the laws by which the apparently inconsistent winds and the resulting weather are regulated. We have established observatories in all parts of the world in which records are kept of almost every passing cloud. The temperature of the air, the pressure of the atmosphere, the hygrometric state of the gaseous envelope, the electrical condition of it, the directions of the winds, and many other points of importance are registered under the direction of competent observers. From the results thus obtained, Professor Dove has already deduced some important facts, and determined the existence of fixed laws regulating at least some of the atmospheric phenomena.

Instruments have from time to time been devoted for registering the above points. Professor Whewell of Cambridge and Mr. Follett Osler of Birmingham, have devised very complete anemometers and rain-gauges; Mr. Osler associating also some other registrations with his very complete instrument. In the Hall of the Polytechnic Institution, and at the Philosophical Institution of Birmingham, an opportunity is afforded of examining what has been done, and of comparing it with the very complete "Atmospheric Recorder", of Mr. Holland, which registers every breeze that blows, or shower that falls, upon the Industrial Building in Hyde Park. Without drawings, it is quite impossible to describe, so as to be understood, the details of the arrangements. But some of its principles may be rendered easily intelligible. In the first place it will be understood that every fact is recorded by the machine itself, by means of a pencil passing over a regularly moving piece of paper, which is carried onward by an attachment with an eight-day clock.

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* From 'The Great Exhibition—London 1851'. The Art-Journal Illustrated Catalogue of the Industries of All Nations. London, Bradbury and Evans, 1851.

The barometer is of the siphon form, of large bore, and upon the mercury in the shortest leg is a float very accurately counterpoised, leaving only sufficient weight to enable it to follow the mercury in its rise and fall. It will be readily conceived that many plans might be adopted for connecting this with a pencil, which should mark every variation. The thermometric arrangement consists of ten mercurial thermometers, of a peculiar form, very accurately balanced, so that the slightest movement of the mercury gave at once a given degree of preponderance on one side or the other. A slip of wood is employed as the hygrometer; this is placed in a tube, through which the air passes freely; every elongation or contraction of this, indicating an excess or deficiency of moisture in the air, is in like manner registered. It will be, of course, understood that a piece of wood forms a very good hygrometer by absorbing moisture or parting with it readily. The electrometer is an insulated conductor, fixed on the highest convenient place, from which a wire is brought down to the instrument, and connected with a fixed disc, near which is fixed a moveable one. When a cloud charged with the electric fluid comes within range of the conductor, the moveable disc begins to slowly pass from the fixed disc to spring, discharging each time a portion of its electricity; it then falls back to the first disc, and remains quiet until another electric cloud approaches; the moving disc, carrying a pencil, records every disturbance.

The rain-gauge is placed on top of the building; it is a foot square. The rain collected in this passes through a pipe into the building, and a float indicates the height of the water and regulates the motion of the pencil. The amount of evaporation going on is by a similar contrivance registered. The direction of the wind is recorded by another pencil which marks the course upon the paper throughout the whole circle of the horizon, or that part through which it passes, and the force of the wind is indicated by the action of the aërial current upon a board one foot square fixed to the vane, and accurately counterpoised, so that the slightest pressure is at once indicated by the movement of the counterpoise. Thus is afforded a means of determining, with the utmost accuracy, every change in the weather, and by thus avoiding all the errors which arise from the carelessness or inaptitude of assistants, we may expect to arrive more satisfactorily at some important facts in climatology beyond those which we already possess. It is interesting to watch the little pencils moving to and fro marking their zig-zag or curved tracts upon the paper, and to observe the peculiar association of one phenomenon with another. The very remarkable groups of instruments which we have been describing are amongst the most striking evidences of Science in the Great Exhibition. By appliances such as these we advance our knowledge and gain power over the phenomena of nature. An instrument by which the navigator is, by a very easy method, enabled to determine the position of the centre of a storm, called by the inventor, Lieut.-Col. Lloyd, Typhodeictor, or storm-pointer, appears to be exceedingly useful. It is now fully determined that the greater storms of the tropics are revolving masses of air, moving onward at a great rate. If a ship becomes involved in one of these, she is soon disabled, but by the investigation of the law of these storms by Lieut.-Col. Reid, an easy method of determining the direction of their movement is given, and thus the mariner is enabled to sail out of their influence. It is to facilitate this that Colonel Lloyd has constructed his storm-pointer. Strange things though meet us here; we have a Storm Indicator, in which leeches crawling out of the water, as is their

habit where there is much free electricity, are made to ring bells*; and we have Count Denni's Man of Steel, composed of many thousand parts, and so contrived that from a figure of about five feet in height, it may readily be converted into one of eight. The ingenuity of these cannot be doubted; but we fear their utility is questionable. They are among the things which sometimes cause us to marvel at the variety of ways in which human invention is frequently applied without the probability of any practical result.

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* *See* MARSHALL, W. A. L.; Festival of Britain, 1951. *Met Mag, London*, 80, p. 166.

Changes in senior appointments within the Meteorological Office

The first six months of 1976 have seen an unusually high incidence of changes at Directorate level of holders of senior appointments.

On 2 January Mr N. Bradbury became Deputy Director (Forecasting) following the retirement of Mr M. H. Freeman. Dr N. E. Rider, on promotion to Deputy Chief Scientific Officer, succeeded Mr Bradbury as Deputy Director (Observational Services).

On 27 April Mr G. A. Corby, on promotion to Under Secretary, succeeded Mr J. K. Bannon as Director of Services in consequence of Mr Bannon's retirement. Mr M. J. Blackwell, on promotion to Deputy Chief Scientific Officer, succeeded Mr Corby as Deputy Director (Communications and Computing).

On 21 June Dr K. H. Stewart, on promotion to Under Secretary, succeeded Mr J. S. Sawyer as Director of Research on the occasion of Mr Sawyer's retirement, which is reported elsewhere in this issue. Mr P. Goldsmith, on promotion to Deputy Chief Scientific Officer, succeeded Dr Stewart as Deputy Director (Physical Research).

OBITUARY

It is with regret that we record the death on 17 March 1976 of Mr D. J. Mackenzie, Higher Scientific Officer, Wyton.

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NOTICES

It is requested that all books for review and communications for the Editor be addressed to the Director-General, Meteorological Office, London Road, Bracknell, Berkshire, RG12 2SZ, and marked 'For Meteorological Magazine'.

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